DEVELOPMENT OF ACTIVELY TUNED VIBRATION ABSORBER FOR WASHING MACHINE

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Abstract- *Vibration can be defined as any motion that repeats itself after an interval of time. Vibration of rigid bodies can be translational, rotational or combination of two. The vibration of a system involves the transfer of its potential energy to kinetic energy and kinetic energy to potential alternately. Vibration is desirable in many applications of real time problem. A system may experience excessive vibration, if it is acted upon by a forced whose excitation frequency nearly coincides with the natural frequency of the system. In such case, the vibration of the system can be reduced by using a vibration absorber. By adding an extra mass, spring and damper on the host structure and by calibrating its natural frequency to be equal with the excitation frequency of the host structure, the device can aid in vibration reduction. The device is known as tuned vibration absorber. In the present research work, an attempt is made to develop an integrated tuned vibration absorber which could retune itself in response to change in excitation frequency for effective damping in washing machine.*

Key words: **Vibration, Tuned Vibration absorber, shape memory alloy, model analysis, harmonic analysis and Damping system.**

1.INTRODUCTION

The vibration absorber, also called dynamic vibration absorber, is a mechanical device used to reduce or eliminate unwanted vibration. It consists of another mass and stiffness attached to the main mass that needs to be protected from vibration. Thus, the main mass and the attached absorber mass constitute a two-degree-of-freedom system, hence the vibration absorber will have two natural frequencies. The vibration absorber is commonly used in machinery that operates at constant speed, because the vibration absorber is tuned to one particular frequency and is effective only over a narrow band of frequencies. Common applications of the vibration absorber include reciprocating tools, such as sanders, saws, and compactors, and large reciprocating internal combustion engines which run at constant speed. In these systems, the vibration absorber helps balance the reciprocating forces. Without a vibration absorber, the unbalanced reciprocating forces might make the device impossible to hold or control. Vibration absorbers are also used on high-voltage transmission lines.

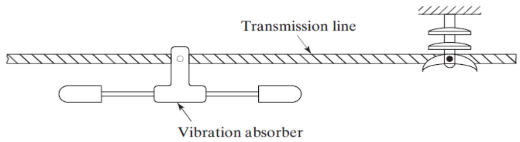

Fig-1: Vibration absorber

In this case, the dynamic vibration absorbers, in the form of dumbbell-shaped devices (Figure 1), are hung from transmission lines to mitigate the fatigue effects of wind induced vibration.A machine or system may experience excessive vibration if it is acted upon by a force whose excitation frequency nearly coincides with a natural frequency of the machine or system. In such cases, the vibration of the machine or system can be reduced by using a vibration neutralizer or dynamic vibration absorber, which is simply another spring-mass system. The dynamic vibration absorber is designed such that the natural frequencies of the resulting system are away from the excitation frequency. We shall consider the analysis of a dynamic vibration absorber by idealizing the machine as a single-degree-of-freedom system. Basavaraj Noolvi et al. [1] have focused on study of vibration absorption characteristic of smart adaptive composite using tuned vibration absorbers. Analysis of cantilever beam with various elastic properties of shape memory alloy and frequency is obtain for elastic properties. Jae Hyun Kim et al. [2] have focused on design and fabrication of dynamic absorber for washing machine. The dynamic Vibration absorber for a Washing machine includes: a mass body; at least one elastic body for supporting the mass body so that the mass body may Vibrate; and a guider for limiting a motion of the mass body, Wherein the dynamic Vibration absorber is attached to the Washing machine generating a Vibration upon operating to reduce the Vibration of the Washing machine.Yukihiro Miyawaki et al. [3] have focused on emulsion for vibration damping material according to various temperature range and thermal dying properties. Jeff Dodd [4] have presented on study of limitation of tuned vibration absorber without damping and with damping system. The amplitude of both system is compared together.

Basically we need to concentrate on the parameters like supply voltages, mechanical parameters and etc. Many of the above parameters can be approximately optimised by solving the problem of Vibration. In a washing machine, vibration of the outer tub is responsible for vibration of the frame and the force then transfers from the supports to the floor. Although springs and dampers also helps in reducing the vibration, it is very much important to efficiently design the coefficients of stiffness and the damping coefficients of these mechanical components. E.Rustighi et al. [5] have focused on study of Tuned vibration of cantilever beam has been realized using shape memory alloy which changes the elastic properties with temperature. W.Bertacchini [6] have focused on the failure pattern observed provides information necessary to introduce a correction to the classical wohler curve for fatigue life of SMA material. Shape memory materials (SMMs) are known for their excellent vibration absorption properties. The current work is focused on study of vibration absorption characteristics of Smart Adaptive Composites (Shape Memory Composites) (SACs), as tuned vibration absorbers. Thin cantilever plate of SAC works as the absorber system in the configuration.

2.OBJECTIVES

The harmonic vibration of a system is an undesirable effect of rotating out of balance mass within the system. So, the vibration of the machine can be suppressed by attaching vibration absorber whose natural frequency is tuned to be equivalent to the excitation frequency of the system. The conventional design of the vibration absorber is effective at particular response frequency.

In the present research work, an attempt is made to develop an integrated tuned vibration absorber which could retune itself in response to change in excitation frequency for effective damping. The following objectives have been framed for washing machine condition with actively vibration absorber.

- The first objective is to develop the tuned vibration absorber with cantilever beam in the CAD modelling software.
- The second objective is to find the natural frequency of the washing machine drum.
- The third objective is to conduct harmonic analysis with excitation frequency in the tuned vibration absorber.

3.METHODOLOGY

The flow chart for development of vibration absorber is created with the help of washing machine application is shown in figure 2. To identify the problem caused in the washing machine due to vibration. Literature Review is used to find solution for the washing machine due to vibration. Tuned Vibration absorber is used in washing machine to reduce the vibration. And to Create a 3D model of washing machine in Cero Parametric 3.0. Preparation of the model before taking it into FEM software such as elimination of bad geometry, simplification of unnecessary parts and improvement of contact regions is done. Basic inputs parameter of analysis is given to Ansys 15.0. This information will allow the model to work properly during simulation and will define the behaviour of the parts during the analysis of FEM inputs. These parameters will control the computational time and the accuracy of results in the simulation. A special analysis of factors is performed in order to define them. Simulation is carried out by the software. Results obtained need to be evaluated and judged as good or bad before presenting them in the report.

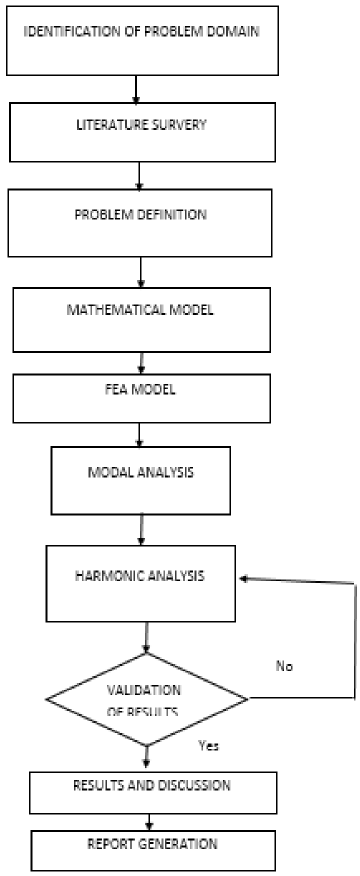

Fig-2: Methodology

4.PRODUCT DESCRIPTION

The WW65M206LMA is a front load washing machine launched in May 2007 by SAMSUNG ELECTRONICS in India(Figure3). It is in competition with the 6.5 Kg washing machine from Bosch, Whirlpool, LG and BPL. The standard Washing machine is powered Motor, delivering 250 W at 700 rpm. It has a permissible loading capacity of 6.5 kg. It is equipped with a Belt Drive and has a spin speed of 700 rpm.. It is best suited for use by customer with front loading of 6.5 Kg. The price of front load washing machine is Rs.32,550/-. The WW65M206LMA was succeeded in creating an entirely new segment that competitors are known to be working on different models to compete against the Washing Machine. The specification of WW65M206LMA Samsung Washing Machine is given in table 1.

Fig-3: Samsung Washing Machine

4.1SPECIFICATION

Table-1: Description of washing machine

Brand	Samsung
Model	WW65M206LMA
Capacity	6.5 Kg
Maximum Rotational Speed	1200 rpm
Installation Type	Free Standing
Form Factor	Front Loading
Colour	White
Control Console	Fully Automatic
Voltage	220 Volts
Batteries Required	No

4.2 FEA MODEL SPECIFICATION

Table-2: Model Specification of washing machine

Net Dimension (WXHXD)	600X850X450 mm
Net Weight	56 Kg
Gross Dimension(WXHXD)	657X890X536 mm
Gross Weight	60 Kg
Voltage/Frequency	220V/50Hz

5.MODAL ANALYSIS

5.1 THEORETICAL CALCULATION FOR NATURAL FREQUENCY OF WASHING DRUM

The natural frequency of the washing drum is calculated with the help of the shaft and rotating disc system. The length of the shaft of washing machine drum is given by 0.5 m. And the diameter of the shaft of washing machine drum is given by 0.175 m. The radius of gyration of the washing machine drum is given by 0.5 m.

Modulus of rigidity, $G = \frac{E}{2(1+v)}$

E = Modulus of Elasticity = $7.1*10^{10}$ Pa

V = Poisson ratio = 0.33

$$G = \frac{7.1 X 10^{10}}{2(1+0.33)}$$

$G = 2.66 X 10^{10} N/m^2$

Mass moment of Inertia, $I=mk^2$

M = Mass of washing drum = 12.5Kg

K = Radius of gyration = 0.5 m

$I =12.5 X (0.5)^2$

$I= 3.125 kg\text{-}m^2$

Torque stiffness of shaft, $K_t=\frac{GJ}{L}$

G = Modulus of rigidity = $2.66*10^{10}$ N/m

L = Length of the shaft = 0.5 m

$$K_t = \frac{2.66 X 10^{10} X \frac{\pi (0.175)^4}{32}}{0.5}$$

$K_t = 4.898 X 10^6 N/m$

Natural Frequency of washing drum,

Natural frequency, $\omega_n = \sqrt{\frac{K_t}{I}}$

ω_n = [illegible] / 3.125

ω_n= 199.263Hz

5.2 MODELLING AND MESHING OF WASHING MACHINE DRUM

It is very important to analyse the behaviour of washing machine drum in modal analysis. In the modal analysis the natural frequency of washing machine drum is obtained. The total deformation of the washing machine drum is calculated from natural frequency. The dimensions of the model are determined from the standard. The CREO model of washing machine drum is shown in figure 4.

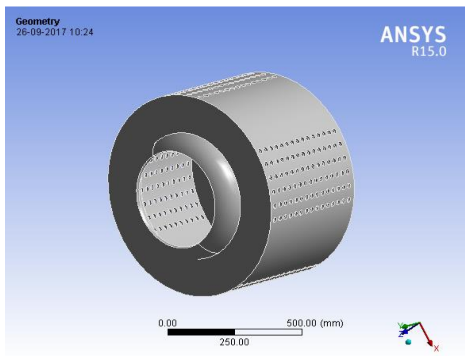

Fig-4: Modelling of Washing Machine Drum

5.3 MATERIAL PROPERTIES OF WASHING MACHINE DRUM

The material properties that are used for the washing drum is shown in the table 3. It is to be noted that the Aluminium alloy material is used for the shell layer of the front loading washing machine drum.

Table-3: Material properties of Washing Machine Drum

Part	Density (kg/m^3)	Young's Modulus (Mpa)	Poisson ratio	Yield Strength (N/m^2)
Aluminium Alloy	2770	71000	0.33	34.3 x 10^6

5.4 MESHING OF WASHING MACHINE DRUM

The meshing was carried out with the following conditions for the washing machine drum, which is shown in the table 4.

Table-4: Mesh Specification

Relevance Center	Fine
Initial Size Seed	Active Assembly
Smoothing	High
Transition	Fast
No of Nodes	73720
No of Elements	34756

5.5 MODAL ANALYSIS

It is very important to analyses the behavior of washing machine drum in modal analysis. The total deformation of the washing machine drum is calculated from natural frequency. The modal analysis of the washing machine drum is done using Ansys 15.0.The Total deformation of washing machine is 4.4614mm for the natural frequency 0Hz.The Total deformation of washing machine is 12.063mm for the natural frequency 193.11Hz. The Total deformation of washing machine is 11.928mm for the natural frequency 341.81 Hz. The Total deformation of washing machine is 7.1636 mm for the natural frequency 441.89 Hz. The total deformation of washing machine drum at 441.89 Hz is shown in fig 5.

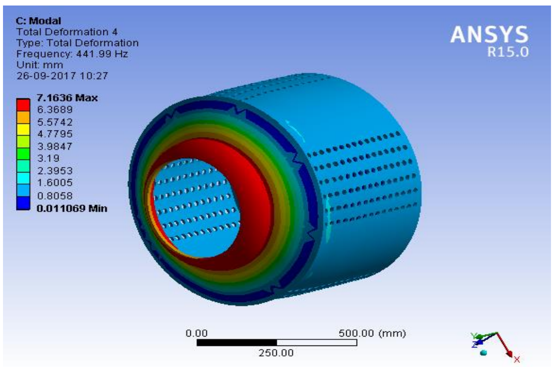

Fig-5: Total Deformation of Washing machine drum at frequency 441.89 Hz

6.HARMONIC ANALYSIS

6.1 THEORETICAL CALCULATION FOR TUNED VIBRATION ABSORBER WITH WASHING MACHINE

The natural frequency of washing machine drum is given by 199.826 Hz. Washing machine should be vibrate with the frequency range 180 Hz- 220 Hz during spinning operation. The mass ratio is fixed with the frequency range.

For Frequency 180 Hz,

$$\frac{\omega}{\omega_2} = \frac{1130.973}{1252.006} = 0.9033$$

$\mu = 0.04149$

For Frequency 220Hz,

$$\frac{\omega}{\omega_2} = \frac{1382.300}{1252.006} = 1.1040$$

$$\mu = 0.03928$$

$\mu = \frac{m_2}{m_1}$ = Mass ratio

M_1= mass of the washing machine drum

With the help of mass ratio, we calculate the mass of absorber(m_2),

$0.04149 = \frac{m_2}{25}$

$$M_2 = 1.03725\text{kg}$$

For tuned vibration absorber, $\omega = \omega_1 = \omega_2$

Stiffness of absorber is calculated from natural frequency,

$\omega^2 = \frac{k_2}{m_2}$

$$k_2 = 41184.782\text{N/m}$$

Amplitude of vibration, $X_2 = \frac{F_o}{K_2}$

$$X_2 = \frac{153}{41184.782}$$

$$X_2 = 3.71 \text{ mm}$$

6.2 MEAN DIAMETER OF SPRING FOR ABSORBER CALCULATION

The mean diameter of spring of the absorber is calculated with the help of spring constant,

Standard of Spring, $K = \frac{Gd^4}{8D^3 N}$

G-Shear Modulus=7.7X10^{12} Pa

d- Wire Size = 0.01m

D- Mean diameter

N- Number of coils

$$D^3 = \frac{7.7X10^{12} X\, 0.01^4}{8X10X41184.782}$$

$$D = 23.37\text{mm}$$

The Mass and spring for tuned vibration absorber is developed for washing machine is shown in the figure 6.

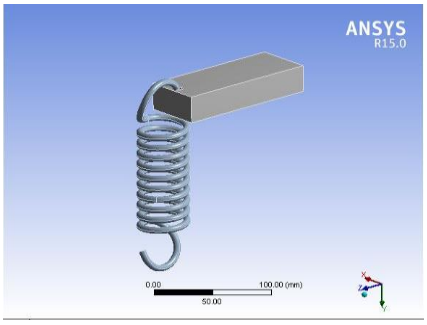

Fig-6 : Mass And Spring Absorber

6.3 MODELLING AND MESHING OF WASHING MACHINE WITH TUNED VIBRATION ABSORBER

It is very important to analyse the behaviour of washing machine with dynamic absorber in Harmonic analysis. In the harmonic analysis the natural frequency of washing machine with dynamic absorber is obtained. The total deformation of the washing machine with dynamic absorber is calculated from forcing frequency. The dimensions of the model are determined from the standard. The CREO model of washing machine with dynamic absorber is shown in figure 7.

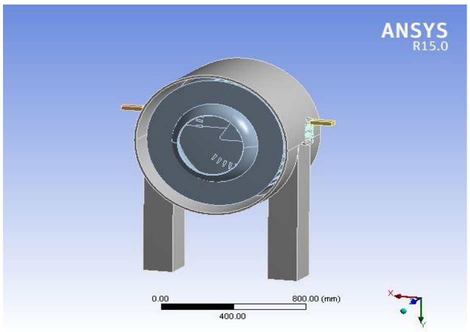

Fig- 7 : Modelling of Washing Machine with dynamic absorber

6.4 MATERIAL PROPERTIES OF WASHING MACHINE

The material properties that are used for the washing machine is shown in the table 6. It is to be noted that the Aluminium alloy material is used for the shell layer of the front loading washing machine drum and outer layer of the washing machine drum. The mass of the dynamic absorber is made of Nickel-Titanium alloy.

Table 6:-Material properties of washing Machine

Part	Density (kg/m^3)	Young's Modulus (Mpa)	Poisson ratio	Yield Strength (N/m^2)
Aluminium Alloy	2770	71000	0.33	34.3 x 10^6
Nickel-Titanium	6450	31000	0.32	1100x10^6

6.5 MESHING OF WASHING MACHINE

The meshing was carried out with the following conditions for the washing machine with drum, which is shown in the table 7.

Table 7: Mesh Specification

Relevance Center	Coarse
Initial Size Seed	Active Assembly
Smoothing	Medium
Transition	Fast
No of Nodes	83678
No of Elements	38332

6.6 HARMONIC ANALYSIS

It is very important to analyse the behaviour of washing machine with dynamic absorber in harmonic analysis. In the Harmonic analysis, the total deformation of the washing machine with dynamic absorber for different forcing frequency is obtained. The total deformation of the washing machine drum is calculated for natural frequency of the washing drum is calculated. The Harmonic analysis of the washing machine drum is done using Ansys 15.0 shown in figure 8.

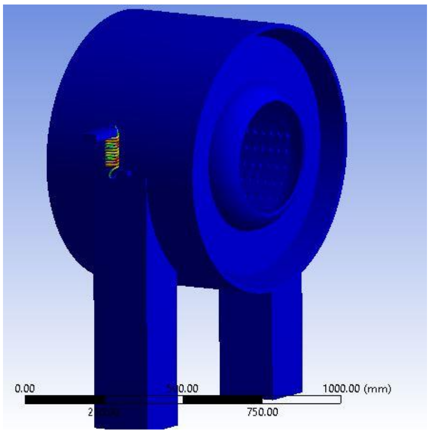

Fig-8: Harmonic Analysis of washing machine with Dynamic Absorber

6.7 FORCE ACTING ON WASHING MACHINE WITH TUNED VIBRATION ABSORBER

In Harmonic Analysis option, right click on it and select insert followed by force. In this force tab, select 'define by' vector and enter the magnitude as load value 153N to the washing machine drum. And in Harmonic Analysis option, right click on it and select insert followed by fixed displacement. In this option, select the mass of the absorber and select the outer layer of drum. In Harmonic Analysis, The Total deformation of washing machine is 1.863xe^{-11} mm for the natural frequency 193.11 Hz. The total deformation of washing machine drum at 193.11 Hz is shown in figure 9.

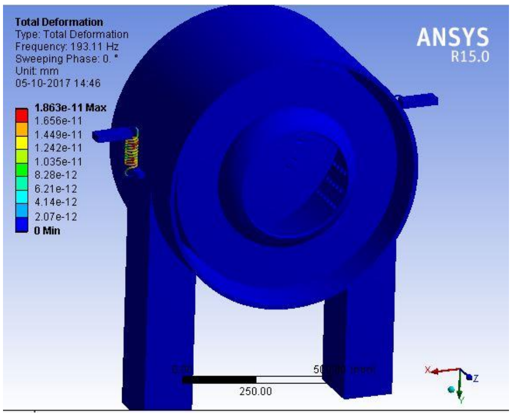

Fig-9: Total Deformation of Washing machine at frequency 193.11 Hz

The Total deformation of washing machine is 0.00075957 mm for the natural frequency 191Hz. The Total deformation of washing machine is 0.0008002 mm for the natural frequency 211Hz.

7.RESULT AND DISCUSSION

7.1 RESULT OF MODAL ANALYSIS

The total deformation of washing machine drum at natural frequency is shown in the table 8.

Table 8: Total Deformation at Natural Frequency in washing machine drum

S.No	NATURAL FREQUENCY (Hz)	TOTAL DEFORMATION (mm)
1	0	4.46
2	193.11	12.06
3	341.81	11.92
4	441.89	7.16

7.2 INFERENCE OF MODAL ANALYSIS

Thus, it was observed that the Total deformation changes by changing the value of natural frequency, the natural frequency of the washing machine drum is 193.11 Hz in the modal analysis. In theoretical method, the natural frequency of the washing machine drum is 199.263 Hz. The percentage of error is 3%.

7.3 RESULT OF HARMONIC ANALYSIS

The total deformation of washing machine at some forcing frequency is shown in the table 9.

Table 9: Total Deformation at Natural Frequency in washing machine drum

S.No	FORCING FREQUENCY (Hz)	TOTAL DEFORMATION (mm)
1	193.11	1.863e-11
2	191	0.00078
3	221	0.00088

7.4 INFERENCE OF HARMONIC ANALYSIS

Thus, it was observed that the Total deformation changes by changing the forcing frequency of the washing machine with dynamic absorber. At Natural frequency of washing drum, there is a deformation of spring due to vibration absorber. The total deformation at natural frequency is 1.86e-11 mm.

8.CONCLUSION

The work involved numerical and analytical studies. The four degree of freedom dynamic model of the washing unit allowed us to predict the motion of the system after damper disengagement. Mathematical modelling is very important and helpful for verification of various design concepts of the drum suspension. Preliminary numerical simulations proved that disengagement of the damper in the spin cycle would reduce the vibration of the frame points. The new concept of a vibration absorber was proposed, mounted in place of the original spring. The mass is controlled by the simple heat unit easily applicable to a washing machine's programmable controller. The novelty is the application of the heating to increase or decrease amount of the dissipated energy.

The mathematical analysis allowed selection of the type of vibration absorber and the required parameters of the vibration absorber in order that the range of the forcing frequency in the washing machine in design assumptions. The analytical analysis is done for calculating the natural frequency of the washing machine drum and vibration absorber is designed within the forcing frequency of 180 Hz-220Hz for the washing machine during the spinning operation. As optimization leads to formation of fault free system, in future we may also concentrate on damper variation to optimize vibration. In this paper we have concentrated on mass by keeping damping coefficient constant. In future we can vary damping coefficient by keeping spring stiffness constant.

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